DOCUMENT RESUME

ED 397 776 IR 017 964

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TITLE Window Presentation Styles and User's Spatial Ability.
PUB DATE 96
NOTE 10p.; In: Proceedings of Selected Research and Development Presentations at the 1996 National Convention of the Association for Educational Communications and Technology (18th, Indianapolis, IN, 1996); see IR 017 960.
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Academic Achievement; Cognitive Processes; Computer Assisted Instruction; Dental Hygienists; *Dental Students; Higher Education; Instructional Effectiveness; Learning Strategies; *Memory; Professional Education; *Screens (Displays); *Spatial Ability
IDENTIFIERS HyperCard; *Memory Load; Visual Displays; *Windows (Software)

ABSTRACT

The purpose of this study was to examine the effects of spatial ability level and window presentation style of tiled and overlapped computer displays on the achievement of dental hygiene students. Participants were 43 first-term Dental Hygiene students enrolled full-time at a University School of Dental Medicine. Phase one of this project consisted of administering the Differential Aptitude Test: Space Relations Subtest to assess each subject's spatial ability. Individuals' scores were examined using a frequency distribution. Participants who ranked greater than the median were classified as having high spatial ability. Those scoring less than the median were placed in the low spatial ability group. Two HyperCard stacks were produced targeting the topic of Ergonomics in Dentistry. The stacks were designed with identical content but differed in information display; two window presentation styles were used. Subjects were randomly assigned by spatial ability level to one of the two treatment groups: tiled or overlapping displays. During phase two, each subject executed the corresponding computer-based tutorial program and completed an identical module test. The tiled and overlapping windowing environments appeared to have served as external memory devices to the user's internal memory source, thereby extending the participant's internal memory capability. Windows appear to alleviate, in part, the memory load of the learner by serving as "markers" of unfinished tasks. Subjects who demonstrated higher spatial ability skills obtained greater educational outcomes from the overlapped window formats. (Contains 31 references.) (Author/AEF)

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ED 397 776

Title:

Window Presentation Styles And User's Spatial Ability

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ABSTRACT

The purpose of this study was to examine the effects of spatial ability level and window presentation style of tiled and overlapped computer displays on the achievement of dental hygiene students.

All forty-three first-term Dental Hygiene students enrolled full-time at a University School of Dental Medicine were the sample who participated in this investigation. Phase one of this project consisted of administering the Differential Aptitude Test: Space Relations Subtest to assess each subject's spatial ability. Individuals' scores were examined using a frequency distribution. Participants who ranked greater than the median were classified as having high spatial ability. Scores less than the median were categorized as the low spatial ability group.

Two HyperCard Stacks were produced targeting the topic of *Ergonomics in Dentistry*. The stacks were designed with identical content and differed by displaying the information in one of the two window presentation styles. Subjects were randomly assigned by spatial ability level to one of two treatment groups: tiled or overlapping displays. During phase two, each subject executed the corresponding computer-based tutorial program and completed an identical module test. A 2 X 2 analysis of variance (ANOVA) was used to analyze the achievement scores. A disordinal interaction in terms of achievement between the two factors was identified with significance at the .01 level.

BACKGROUND

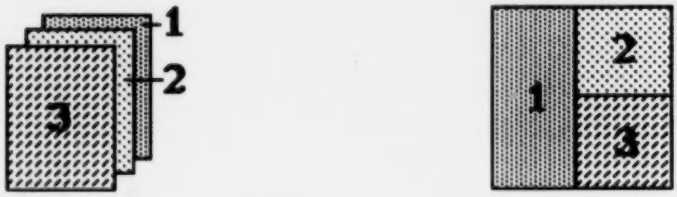
Despite limited theoretical and empirical research to justify their usage, windowing environments are widely used as primary computer interfaces. The visual display mechanism of a window environment appears to capitalize on the spatial organization of the computer screen. Windows subdivide the computer screen into distinct sections each containing different bits of information. The information contained in the windows can be viewed simultaneously using tiled displays or in segments via overlapping techniques.

> "Windowing systems, according to their proponents, are inherently easy to use and automatically conducive to user productivity. But, while it is clear that some windowing systems offer benefits to some users under some conditions, we still have little understanding of the implementation, user, and task parameter that lead to increased productivity and satisfaction" (Billingsley, 1988, p. 413).

Since their inception in the early 1970's, windows have been *assumed* to be useful based on user feedback and personal preference indicators (Miller & McMillan, 1984). To date, however, little research has been conducted on the effects of the use of the various windowing techniques (Jonassen, 1989, Marshall, 1986, Bly & Rosenberg, 1986, Cohen, 1985, and Bury, Davies, & Darnell, 1985). Therefore, careful examination of the desktop screen design may be an essential component for window utilization.

Windows are commonly employed in computer-based educational programs to display information using the same or different data, to access peripheral program, and to provide links to other multimedia workstations. Two common types of windows are defined by their placement on the screen. The first window configuration is termed "overlapped" i.e. one window obscuring another. Overlapped or stacked windowing displays simulate a realistic desktop with sheets of layered paper. In an overlapping window environment, the learner is only permitted to view a section of the window because the windows are overlaying one another producing a stacked effect. An overlapping window system requires a learner to utilize his/her visual skills in a three-dimensional arena.

The second window display, referred to as "tiled" i.e. windows not obscured by one another. In a tiled display, one can view each window on the display screen without any obstruction from each of the other windows (Miller & McMillan, 1984 and Jonassen, 1989). Tiled window screens display information to users so that they may view the windows simultaneously. In a tiled window system the learner draws on his visual abilities by interacting with the program in two-dimensional space. See Figure 1 for the visual representations of overlapping and tiled window systems.



Overlapping Window System **Tiled Window System**

Figure 1. Window Systems

Limitations in human memory are fundamentally important considerations with regard to cognitive performance of any task including the manipulation of a window system. Tiled and overlapped window configurations serve as external memory devices to the user's internal memory, therefore extending the participant's internal memory capability. Windows tend to alleviate, in part, the memory load of the learner by serving as "markers" of unfinished tasks as well as enabling individuals to view more than one data set at a time. (Billingsley, 1988 and Card, Pavel, & Farrell, 1984). A dilemma may occur with the learner's new found "cognitive freedoms". New cognitive strategies and encoding requirements may need to be developed by the learner when in the windowing environment, a condition which may already be cognitively overloading to the user (Sullivan & Stephen, 1985). Researchers have attempted to compensate for the potential memory load dilemma by choosing window environments that depict true world experiences as well as by providing practice to the user within the windowing display.

Windows appear to serve as *tools* for learners which makes it possible for them to hold information in memory, organize, and retrieve it. Documented research does not clearly explain how this tool functions as a memory device. However, researchers do suggest that this storage structure for visual information should be compatible with human perception, retention, comprehension, and retrieval processes (Reilly & Roach, 1986). A global presentation of the information is afforded by the tiled displays. Tiled configurations permit the user to divide the display into small chunks of information, view several bits of information simultaneously, organize it, and hold the data in working memory. "A tiling system makes it easy for users to keep track of all open windows by visually inspecting the display..." (Billingsley, 1988, p. 420).

Overlapped displays require active participation of the user's ability to hold information in the working memory from one display to another and spatially relate the data. In this case, the windows serve as data reminders or "markers". The user must be able to infer that information is present even though it is covered by another window (Norman, Weldon, & Shneiderman 1986). An overlapping system makes it possible to 'lose' or forget about windows that are covered by other windows (Bury et al., 1985). Learners must be spatially astute when using the overlapped screen design.

Jonassen (1989) has identified six major purposes of windows including operational qualities, navigational functions, organizational/explicative modalities, explanatory/help factors, metaphorical operations and exploratory devices. To date, little empirical and theoretical research has been conducted on the effects of the use of the various windowing techniques (Jonassen, 1989, Marshall, 1986, Bly & Rosenberg, 1986, and Bury et al., 1985). Therefore, the need for experimental research in this area is necessary for the improvement of current and future computer-based instructional packages.

Miller and McMillan (1984) infer that tiling and overlapping window choices are "basically a matter of personal preference" rather than based on specific cognitive strategies or skills (p. 98). This theory has been challenged in the proposed research project. It was postulated that performance would be enhanced when selective matching occurs between level of spatial ability and windowing style. It was hypothesized that individuals who demonstrate high spatial ability would perform better when using overlapped windowing environments. In contrast, low spatial ability learners were expected to have better educational outcomes when using tiled windowing displays.

Norman et al. (1986) express a similar thought: "When there is a mismatch between the user's visual expectations about the pattern of the display and the actual operation of the system, it is hypothesized that performance will be impaired. On the other hand, if multiple windows and coordinated screens are used in a manner that supports the user's expectations, they will become powerful tools for creating new work environments and increasing the visual scope

of the user" (p. 231). The authors have suggested that the learner's spatial ability must be considered when designing and using window screen designs in computer-based instructional programs.

By using windows, data no longer is solely represented in two-dimensions via tiled displays; but rather three-dimensionality is introduced using overlapped techniques. These technological changes require that learner factors, especially spatial ability level should be considered in computer-based program design. To date, documented research regarding the effects that spatial ability may have on performance outcomes has not been adequately addressed when windowing presentation styles are developed to display computer program data.

Primary mental abilities such as spatial ability are "cognitive skills that enable individuals to learn, think, and reason" as stated by Thurstone (1938) cited in Jonassen and Grabowski (1993, p. 63). Jonassen and Grabowski (1993) add to this definition by stating that spatial qualities include the use of: "...visual skills, spatial manipulation, similarity of visuals, and imagining how visuals might appear in other orientations" (p. 64). Bishop (1980) has identified two categorical demarcations for spatial ability which make a distinction between "low-level spatial abilities, which require visualization of two-dimensional configurations but no mental transformations of those visual images, and high-level spatial abilities, which require visualization of three-dimensional configurations and the mental manipulation of these images" (cited in Cohen, 1985, p. 29). The definition of spatial ability in this study was drawn from Bishop's second category and defines spatial ability as both the visualization and manipulation of objects (windows) in space.

Learners possess a wide range of spatial ability levels. Continuing research has investigated differences in spatial knowledge: how individuals acquire, manipulate, encode, and retrieve information (Thorndyke, 1980). Highly spatial individuals possess the aptitude to remain unconfused by the changing orientation in which the spatial configuration may be presented (McGee, 1979). Spatially astute subjects tend to use visualization strategies more effectively, therefore, exhibiting better visualization abilities. Educators may overlook the learner's spatial ability and the differences among learners' abilities when designing instructional materials. Computer program developers may also be ignoring this mental ability when creating computer-based packages.

Windows, one type of graphical user interface, call upon user's spatial ability to a high degree. Tiled displays represent data in two-dimensional space whereas overlapping environments depict information in three-dimensional space. Billingsley (1988) comments on window presentation style by adding that: "This attribute specifies the possible spatial relationships between windows and, to some degree, the types of operations that can be performed on them" (p. 419).

If spatial ability levels interact with the screen designs and memory requirements of the tiled and overlapping window environments, then one should consider the spatial ability of the learner when selecting appropriate screen displays for computer-based instructional packages. The purpose of this study was to investigate the interaction between spatial ability and window presentation styles (tiled, overlapping).

METHOD

This study followed the format of Aptitude-Treatment-Interaction research in that the aptitude of learner spatial ability was contrasted with two window presentation formats. The research design employed in this study is depicted in Figure 2.

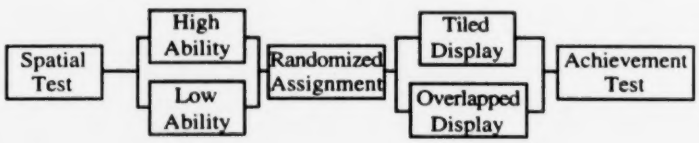


Figure 2. Research Design

The research sample was comprised of all forty-three, first-term Dental Hygiene students who were enrolled full-time at a University School of Dental Medicine Dental Hygiene Program. All subjects were volunteers for this study and represented 100% participation of the Dental Hygiene class. Forty-one subjects (95.3%) were female and two (4.7%)

were male. The majority of the subjects were 18-25 years of age, had a variety of educational backgrounds and computer proficiency levels.

The Differential Aptitude Test: Space Relations Subtest was administered to all Dental Hygiene students. Students were dichotomized into high and low spatial ability groups using the median score, 26.8, as the "cut off" point. Students scoring above the median were defined as high spatial ability and those scoring below the median were categorized as low spatial ability. Students from each group were randomly assigned to one of two treatment groups, tiled or overlapped, using stratified random assignment procedures.

Two HyperCard Stacks were produced by the author targeting the topic of *Ergonomics in Dentistry*. The tutorial stacks were designed with identical content and only differed by displaying the information in one of the two presentation styles, tiled or overlapped displays. Information was presented using various forms such as text, audio, digitized voice responses, diagrams, figures and realistic digitized images.

At the completion of the assigned computer-based treatment, an achievement examination consisting of 31 questions assessing subjects' knowledge of the content presented in the program was administered to all subjects. The completion of all parts of this study took each subject approximately one hour.

RESULTS

A 2 X 2 ANOVA was used to analyze the research results. Spatial ability and window presentation styles were the two factors.

The means and standard deviations of the achievement scores by spatial ability and type of window presentation style are presented in Table 1. As can been seen from the table, the size of the four research groups ranged from 10 to 12 subjects. The total possible score that could have been attained on the achievement test was 31.

The Statistical Package for the Social Sciences (SPSS) Version 5.0 was used to analyze the data. Table 2 displays the ANOVA summary for the achievement scores. The interaction between spatial ability level and window presentation style produced an F value of 7.53 which was significant at the .01 level. The resulting disordinal interaction is plotted in Figure 3. Since a significant interaction was obtained, examination of main effects were not appropriate. The plot indicates that subjects who were identified as having high spatial ability performed significantly better in the overlapped window environment. Conversely, low spatial ability subjects scored significantly higher using the tiled displays.

Table 1

Means and Standard Deviations of Achievement Scores by Spatial Ability and Type of Window Presentation Style

	Presentation Style					
	Tiled			Overlapped		
Spatial Ability	n	M	SD	n	M	SD
High	11	22.73	1.79	12	24.42	1.93
Low	10	24.30	2.50	10	22.20	2.78

Table 2

ANOVA Summary Table for Achievement Scores

Source	df	MS	F	p value
Spatial Ability (A)	1	1.11	0.22	0.64
Presentation Style (B)	1	0.45	0.09	0.77
A X B	1	38.37	7.53	0.01
Error	39	5.10		

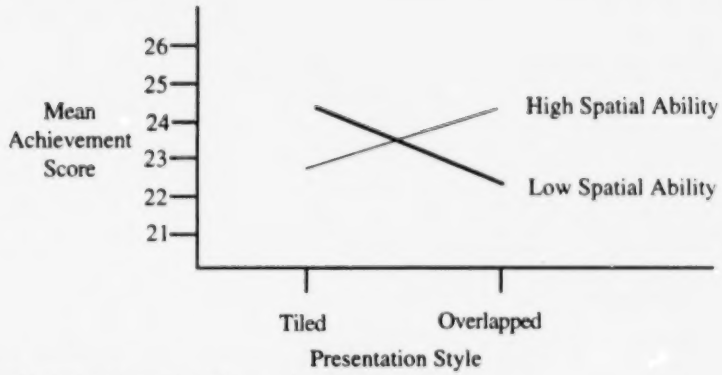


Figure 3. Interaction of Level of Spatial Ability and Presentation Style

DISCUSSION

The tiled and overlapping windowing environments appear to have served as external memory devices to the user's internal memory source, thereby extending the participant's internal memory capability as predicted by Billingsley (1988) and Card et al. (1984). Windows appear to alleviate, in part, the memory load of the learner by serving as "markers" of unfinished tasks via overlapping displays or by enabling individuals to view more than one data set at a time through tiled displays.

In this study, subjects who demonstrated higher spatial skills obtained greater educational outcomes from the organization of the overlapped window formats. This may be in part due to the cognitive organization ability of the highly spatial individuals who were able to mentally hold and relate the data. The overlapped windowing system permitted the highly spatial learners to "mark" data and employ their three-dimensional visualization skills. The overlapped displays required users to hold information in working memory from one display to another and to spatially relate the material.

Conversely, tiled displays enabled low spatial ability subjects to perform better when viewing information that was presented side by side in a two-dimensional configuration via the tiled windowing environment. Tiled configurations permitted the user to fully view several bits of information simultaneously and hold the data in the internal memory source. Since individuals with low spatial ability have limited visualization skills, these subjects were better able to remember tiled program data because the information was displayed with open windows permitting full visual inspection

of the screen displays. The low spatial ability group was not required to mentally manipulate and relate the data, as in a overlapped windowing system. The tiled display appears to better complement the low visualization ability of the low spatial ability learner group. When window formats were properly matched to the learner's spatial capability more successful educational outcomes where obtained.

It is interesting to note that students exhibiting high spatial abilities performed poorly when using tiled windows. The reason for this finding is not clear. However, it may be concluded that these learners prefer to impose their own spatial schemata on the information presented and do not perform well when an incompatible, program defined schema such as presented in the tiled treatment is imposed on them. Further research is clearly needed to investigate this issue.

The disordinal interaction found in this study strongly suggests that the factor of user spatial ability has significant implications for the types of window formats which will be most beneficial. Clearly, those students with high spatial skills did profit most from the perceptually more complex overlapped environments, while those with low spatial abilities needed the more global presentation of information afforded by tiled windows. The cognitive process, spatial ability, appears to be one of the factors that needs to be considered when selecting computer-based instructional packages that exhibit windowing systems. Compatibility of the learner's spatial ability level with the appropriate window environment has been shown to benefit the educational outcomes. Therefore, additional research studies paralleling and extending the current project are recommended.

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